



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ^S: C07K 15/28, C12N 5/20, 5/28, C12P 21/08, A61K 39/42, 39/395	A1	(11) International Publication Number: WO 94/17105 (43) International Publication Date: 4 August 1994 (04.08.94)
(21) International Application Number: PCT/US93/01168 (22) International Filing Date: 29 January 1993 (29.01.93) (71) Applicant: MEDIMMUNE, INC. [US/US]; 35 West Watkins Mill Road, Gaithersburg, MD 20878 (US). (72) Inventor: JOHNSON, Leslie; 13545 Embassador Drive, Germantown, MD 02874 (US). (74) Agent: OLSTEIN, Elliot, M.; Carella, Byrne, Bain, Gilfillan, Cecchi & Stewart, 6 Becker Farm Road, Roseland, NJ 07068 (US).		(81) Designated States: AU, CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i>

(54) Title: HUMAN-MURINE CHIMERIC ANTIBODIES AGAINST RESPIRATORY SYNCYTIAL VIRUS

DESIGN OF CDR-GRAFTED ANTI-RSV F PROTEIN V_H

Cln Val Cln Leu Val Cln Ser Gly Ala Glu Val Lys
 Cln Val Cln Leu Val Cln Ser Gly Ala Glu Val Lys
 Cln Val Cln Leu Cln Cln Ser Gly Ala Glu Leu Val
 Ser Cys Lys Ala Ser Gly Tyr Thr Phe Asn Ser Tyr
 Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys ASP Tyr
 Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys Asp Pyl
 Pro Gly Cln Gly Leu Glu Trp Met Gly Ile Ile Asn
 Pro Gly Cln Gly Leu Glu Trp Ile Gly Trp Ile Asp
 Pro Glu Cln Gly Leu Glu Trp Ile Gly Trp Ile Asp
 Ala Cln Lys Phe Cln Gly Arg Val Thr Met Thr Arg
 Asp Pro Lys Phe Cln Gly Arg Val Thr Met Thr Arg
Asp Pro Lys Phe Cln Gly Lys Ala Ser Ile Thr Ser
 Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala
 Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala
 Leu Cln Leu Ser Ser Leu Thr Ser Glu Asp Thr Ala
 Thr Ser Ser Phe Asp Phe Trp Gly Cln Gly Thr Thr
 Thr Ser Ser Phe Trp Gly Cln Gly Thr Thr Leu Thr
 / J.

Lys Pro Gly Ala Ser Val Lys Val Human HVJ V_H
 Lys Pro Gly Ala Ser Val Lys Val "CDR Grafted"
 Arg Pro Gly Ala Leu Val Lys Leu Marine 1308F
 Tyr Met His Trp Val Arg Cln Ala
Ile Ile Tyr Trp Val Arg Cln Ala
 Tyr Ile Tyr Trp Val Lys Cln Arg
 Pro Ser Gly Gly Ser Thr Ser Tyr
Pro Glu Asn Gly Asn Thr Val Phe
 Pro Glu Asn Gly Asn Thr Val Phe
Asp Thr Ser Thr Ser Thr Val Tyr
 Asp Thr Ser Thr Ser Thr Val Tyr
 Asp Thr Ser Ser Asn Thr Ala Tyr
 Val Tyr Tyr Cys Ala
 Val Tyr Tyr Cys Ala Tyr Tyr Gly
 Val Tyr Tyr Cys Ala Tyr Tyr Gly
 / O
 Leu Thr Val Ser Ser
 Val Ser Ser

(57) Abstract

This invention relates to a human antibody which contains at least one CDR from each variable heavy and variable light chain of at least one murine monoclonal antibody, (preferably a neutralizing antibody) against respiratory syncytial virus. The invention also relates to the murine antibody being an antibody against RSV-F protein. In a preferred embodiment the CDR contains three complementarity determining regions from the variable heavy and variable light chain of at least one murine antibody against RSV-F protein.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LU	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

Human-Murine Chimeric Antibodies Against Respiratory Syncytial Virus

BACKGROUND

Respiratory syncytial virus (RSV) is the major cause of acute respiratory illness in young children admitted to hospitals, and the community practice will treat perhaps five times the number of hospitalized children. It is therefore, the most common cause of lower respiratory tract infection in young children. While the majority of community-acquired infections resolve themselves in a week to ten days, many hospitalized children, especially under six months of age require assisted ventilation.

Efforts to produce an effective vaccine have been unsuccessful (8). A major obstacle to vaccine development is safety; the initial formalin inactivated RSV vaccine caused an increased incidence of RSV lower respiratory tract disease and death in immunized children upon exposure to virus (5).

Recently, the drug ribavirin has been licensed for therapy of RSV pneumonia and bronchiolitis (2,3); its value is controversial (4). Although ribavirin has shown efficacy (9), the drug has to be administered over an 18 hour period by aerosol inhalation. In addition, the level of secondary infections following cessation of treatment is significantly higher than in untreated patients.

Studies have shown that high-titered RSV immunoglobulin was effective both in prophylaxis and therapy for RSV infections in animal models (6, 7). Infected animals treated with RSV immune globulin, showed no evidence of pulmonary immune-complex disease (6, 7).

Even if RSV hyperimmune globulin is shown to reduce the incidence and severity of RSV lower respiratory tract infection in high risk children, several disadvantages may

limit its use. One drawback is the necessity for intravenous infusion in these children who have limited venous access because of prior intensive therapy. A second disadvantage is the large volume of RSVIG required for protection, particularly since most these children have compromised cardiopulmonary function. A third disadvantage is that intravenous infusion necessitates monthly hospital visits during the RSV season which places these children at risk of nosocomial RSV infection (1). A final problem is that it may prove to be very difficult to select sufficient donors to produce a hyperimmune globulin for RSV to meet the demand for this product. Currently only about 8% of normal donors have RSV neutralizing antibody titers high enough to qualify for the production of hyperimmune globulin.

Another approach may be the development of monoclonal antibodies with high specific neutralizing activity as an alternative to hyperimmune globulin. It is preferable, if not necessary, to use human monoclonal antibodies rather than murine or rat antibodies to minimize the development of human anti-rodent antibody responses which may compromise the therapeutic efficacy of the antibody or induce immune-complex pathology. However, the generation of human monoclonal antibodies with the desired specificity may be difficult and the level of production from human cell lines is often low, precluding their development.

An alternative approach involves the production of human-mouse chimeric antibodies in which the genetic information encoding the murine heavy and light chain variable regions are fixed to genes encoding the human heavy and light constant regions. The resulting mouse-human hybrid has about 30% of the intact immunoglobulin derived from murine sequences. Therefore, although a number of laboratories have constructed chimeric antibodies with mouse

variable and human constant domains (10-18), the mouse variable region may still be seen as foreign (19).

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a complementarity determining region (CDR)-grafted human antibody which contains at least one CDR from each variable heavy chain and variable light chain of at least one murine monoclonal antibody, against the RSV antigen. Preferably, the murine monoclonal antibody is a neutralizing antibody. It is also preferable that said murine antibody is an antibody against RSV F antigen.

The term "animal" as used herein is used in its broadest sense includes mammals including humans.

DETAILED DESCRIPTION OF THE DRAWINGS

The drawings depicted and described herein are intended to further illustrate the present invention and are not intended to limit the invention in any manner whatsoever.

Figure 1 shows the amino acid (AA) sequence design of CDR-Grafted anti-RSV F glycoprotein V_H . The figure depicts the AA sequence for the human HV3 V_H before grafting, CDR grafted V_H , and murine MAb1308F V_H from which the CDR sequence was grafted. The heavily underlined regions identify the CDR sequence which was grafted into the human HV3 V_H and each of the three regions is identified as CDR1, CDR2 and CDR3, respectively.

Figure 2 shows the amino acid (AA) sequence design of CDR-Grafted anti-RSV F Protein V_L . The figure depicts the AA sequence for the human K102 V_L before grafting, CDR grafted V_L , and murine MAb1308F V_L from which the CDR sequence was grafted. The heavily underlined regions identify the CDR sequence which was grafted into the human

K102 V_L and each of the three regions is identified as CDR1, CDR2 and CDR3, respectively.

Figure 3 depicts the oligonucleotides used to make Hul308V_H, the sequences which are underlined are the specific primer sequences.

Figure 4 depicts the oligonucleotides used to make Hul308V_L, the sequences which are underlined are the specific primer sequences.

Figure 5 depicts the plasmid construction of the expression vectors for Humanized 1308.

Figure 6 depicts a graph of the Neutralization of RSV as percent neutralization versus ng MAb per reaction for neutralizing with Cos Hul308F and with Mul308F.

DETAILED DESCRIPTION OF THE INVENTION

Applicants have found that transplantation into a human antibody, of only the genetic information for at least one CDR from each of the variable heavy and variable light chain derived from murine monoclonal antibody against RSV antigen, is effective for the prevention and treatment of RSV in animals. Preferably the murine antibody is a neutralizing antibody against RSV. Another aspect of the present invention provides for the murine antibody to be an antibody against RSV F antigen. Preferably, the murine antibody is neutralizing antibody against RSV F antigen. The substitution of the mouse CDR's into the human variable framework segments minimizes the potential for human anti-mouse antibody (HAMA) responses while retaining binding affinity and specificity for antigen, RSV F protein. Since, the CDR's do not contain characteristic murine or human motifs, the human antibodies containing the murine antibody CDR's are essentially indistinguishable from completely human antibodies, thereby, minimizing the human antibody

response while retaining binding affinity and specificity for RSV F antigen.

The development of a humanized antibody against RSV F antigen began with a murine antibody against RSV F antigen. Examples of murine antibodies of this type are: MAb 1436C, MAb 113, MAb 112, MAb 151, MAb 1200, MAb 1214, MAb 1237, MAb 1129, MAb 1121, MAb 1107, MAb 131-1, MAb 43-1, MAb 1112, MAb 1269, MAb 1243, MAb 1331H, MAb 1308F and MAb 1302A (see citation 21).

An aspect of the present invention provides that the CDRs of the human antibody are comprised of three complementarity determining regions (CDRs) from each variable heavy and variable light chain of the murine antibody.

The murine antibodies against RSV F antigen have been mapped by competitive binding and reactivity profiles of virus escape mutants to three broad antigenic sites (A, B, C) containing 16 distinct epitopes (20). The epitopes within antigenic sites A and C have shown the least variability in natural isolates.

Therefore, another aspect of this invention provides for a human antibody containing at least one CDR from each variable heavy and variable light chain of at least one murine antibody against RSV F antigen which is specific for antigenic site A or C. Preferably, this invention provides for the murine antibody against RSV F antigen specific for antigenic site C, where the murine antibody is MAb 1308F.

A preferred embodiment of this invention is a human antibody which contains CDR's of the variable heavy chain of murine antibody MAb 1308F against the RSV F antigen. The CDR variable heavy chain of MAb 1308F comprises three CDRs having the following amino acid sequences: Nos. 31 to 35, 47 to 60 and 99 to 106. In addition, this embodiment contains CDR's of a variable light chain of MAb 1308F of murine

antibody against RSV F antigen. The CDR variable light chain comprises three CDR's having the following amino acid sequences: Nos. 24 to 34, 50 to 56 and 89 to 97.

An additional aspect of applicants' invention is a process for preventing or treating RSV infection comprising administering to the animal an effective amount of a human antibody containing at least one CDR from each variable heavy and variable light chain, of at least one murine antibody against RSV F antigen.

Another aspect of applicants' invention is a composition comprising administering an effective amount of the human antibody as described above in conjunction with an acceptable pharmaceutical carrier. Acceptable pharmaceutical carriers include but are not limited to non-toxic buffers, fillers, isotonic solutions, etc.

The composition of Applicant's invention may be administered topically or systemically. Examples of topical administration are intranasal administration and inhalation of an aerosol containing the human antibody composition. Systemic administration may be accomplished by intravenous or intramuscular injection of the human antibody composition.

A preferred aspect of Applicants' invention is that the human antibody is administered as part of a plurality of human antibodies against RSV F antigen. These antibodies can be against the same or different epitopes of the RSV F antigen.

Additionally, the human antibody of this invention can be used clinically for diagnosing respiratory syncytial virus in patients. Because of their affinity for RSV F antigen these human antibodies can be used in known diagnostic assay procedures for detecting the presence and concentration of RSV F antigen cells in samples, e.g., body

fluids. The human antibodies of the present invention can for example be attached or bound to a solid support, such as latex beads, a column, etc., which are then contacted with a sample believed to contain RSV F antigen.

Applicants' development of human antibodies against RSV, began with murine hybridoma cells producing murine monoclonal antibodies which have been shown to neutralize RSV in vitro and protect cotton rats against lower respiratory tract infection with RSV.

One such antibody was selected, which is specific for antigenic site C, to produce mouse-human chimeric antibodies. This antibody was chosen on the basis that it: (i) reacted with a large number of virus strains tested (at least 13 out of 14 isolated); (ii) retained neutralizing activity against virus escape mutants selected with other anti-F antibodies and (iii) blocked RSV replication when administered at low doses to cotton rats by intranasal route prior to virus challenge. The antibody showed significant reduction in pulmonary virus titer among antibodies in that respective region. Murine antibody 1308F, specific for the C region of RSV F protein, was chosen as the initial target for humanization.

In summary, the human antibodies were constructed as follows: the RNA was extracted from the murine antibody-producing cell line, the murine variable regions which are responsible for the binding of the antibody to RSV were cloned and sequenced, resulting in the identification of the murine antibody CDRs. Then a human variable heavy and light chain framework sequence having the highest homology with the variable heavy and light chain murine antibody, was selected. A human framework sequence such as described above is best able to accept the murine-derived CDRs.

The murine 1308F variable heavy chain was compared to various human germline genes, the highest homology was to the human germline gene HV3. The two sequences were 62% homologous overall and 65% in the framework regions. Significantly, there is good homology at the junctions of the CDR segments and the frameworks with the exception of the 5' end of FR2. The murine derived variable heavy chain CDRs were then substituted into the variable heavy chain human germline gene HV3. The mouse and human sequences as well as that of a potential CDR-Grafted combination of the two is shown in Figure 1.

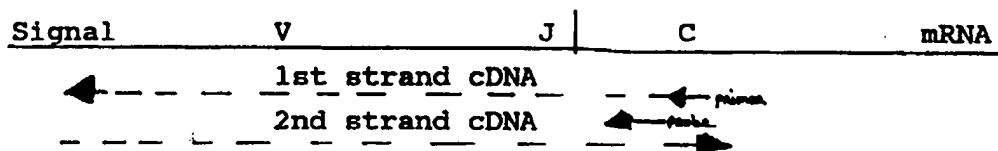
A similar analysis of the V_L region revealed high homology to the human germ line V-Kappa gene K 102. The alignment of these sequences is shown in Figure 2. In this case the homology is 62% overall and 73% in the framework regions. The murine-derived variable light CDRs were then substituted into the human variable light chain of human germline gene K102. In each case a human J-region can be selected which is identical to the mouse sequence.

Therefore, human antibodies are expressed and characterized relative to the parental murine antibodies to be certain that the genetic manipulation has not drastically altered the binding properties of the antibodies.

Applicants present herein examples which are further illustrative of the claimed invention but not intended to limit the invention.

Examples 1cDNA cloning and sequencing of anti-RSV F Protein antibody 1308F

cDNA copies of the V_H and V_L of the target antibody were generated as follows. The first strand cDNA reaction was carried out using AMV reverse transcriptase and a phosphorylated oligonucleotide primer complementary to a segment of the mRNA coding for the constant region of the particular heavy or light chain isotype. For 1308F the isotype is gamma1, kappa and the specific oligonucleotides were 5'AGCGGATCCAGGGGCCAGTGGATAGAC complementary to codons 129-137 of the CH1 region of the murine Gamma1 gene, and 5'TGGATGGTGGGAAGATG complementary to codons 116-122 of the murine C-kappa gene. The primer anneals to a segment of the mRNA adjacent to the variable region. Second strand cDNA synthesis was carried out using RNase H and E. coli DNA polymerase I, as described by Gubler and Hoffman (Gene 25, 263, 1983), followed by T4 DNA polymerase to assure that blunt ends are produced.



The ds-cDNA was ligated into pUC18 which had been digested with restriction endonuclease SmaI and treated with alkaline phosphatase. The ligation was used to transform E. coli DH5a by the method of Hanahan (J. Mol. Biol. 166;557, 1983). Oligonucleotide probes corresponding to C-region sequence lying between the first strand cDNA primer and the V-region were used in colony hybridizations to identify

transformants carrying the desired cDNA segment. The specific probe sequences were GGCCAGTGGATAGAC complementary to codons 121-125 of murine CH1 regions and TACAGTTGGTGCAGCA complementary to codons 110-115 of c-Kappa, respectively. Candidate plasmids, isolated from colonies which were positive in the hybridization, were analyzed by digestion with restriction endonucleases Eco RI and Hind III to release the cDNA insert. Those with inserts of 400-500bp were subjected to DNA sequencing.

The cDNA inserts were inserted into M13 mpl8 and mpl9 for the determination of the DNA sequence on both strands. Single stranded DNA from the resulting recombinant bacteriophage was isolated and sequenced by the dideoxy chain termination method (Proc. Nat. Acad. Sci. USA 74: 5463, 1977).

In order to confirm that the pair of rearranged and somatically mutated V gene cDNA's isolated from the 1308F hybridoma represented those which were in the 1308F antibody, a single-chain Fv gene was generated, expressed in and secreted from mammalian cells, then assayed for binding to RS virus. Competition binding experiments then were used to demonstrate the identity of the binding site.

Example 2

Design and assembly of human 1308F V_H and V_L

The CDR regions of the V_H and V_L were identified by comparing the amino acid sequence to known sequences as described by Kabat (38). In order to select the human framework sequences best able to accept the mouse derived CDR sequences in a conformation which retains the structure of the antigen combining site, the following strategy was employed. First, the sequence of the murine V_H and V_L regions will be compared to known human sequences from both

the Genbank and NBRF protein databanks using the Wordsearch program in the Wisconsin package of sequence manipulation programs (Nucleic Acid Res. 12;387). The best several human V-regions were then analyzed further on the basis of similarity in the framework regions, especially at the junctions of the framework and CDR regions (see Figures 1 and 2).

The CDR-grafted V_H region together with the respective leader sequence of the human v-region gene was synthesized de novo using four overlapping oligonucleotides ranging from 100-137 nucleotides in length (see Figure 3). The oligonucleotides were first allowed to anneal in pairwise combinations and extended with DNA polymerase to generate approximately 200bp ds DNA fragments with an overlapping region. the fragments were then mixed and subjected to PCR using primers at the 3' end of one fragment and the 5' end of the other fragment. The only product which can be formed under these condition is the full length V_H segment. The specific primer sequences are underlined in Figure 3. An endonuclease Sac I site was included at the 3' end of the V_H sequence in order to join it to a human constant region gene segment.

The CDR-grafted V_L region was synthesized in a similar way (see Figure 4). In this instance the initial 200bp fragments were amplified separately and inserted into separate plasmids. The fragment coding for the amino terminus was cloned into a pUC18 derivative as an NcoI-SmaI fragment while the fragment coding for the carboxyl-terminus was cloned as a SmaI to Hind III fragment. The fragments were subsequently combined via a SmaI site at the junction. The oligonucleotides are indicated in Figure 4. A Hind III site was included near the 3' end of the gene segment in order to join it to a human C-kappa gene.

Example 3

Construction of Vectors for 1308F expression

The NcoI-SacI fragment representing the humanized V_H was joined to a SacI -NotI fragment representing a human c-Gamma I CDNA and inserted into pS 18 (which is pUC 1 8 with NcoI and NotI restriction sites incorporated into the polylinker region between the BamHI and KpnI sites). The humanized 1308F-gammal gene on a SacI-NotI fragment was then combined with a PvuI-NotI fragment from pSJ37 carrying a poly A addition site and a PvuI-SacI fragment from pSV2-dhfr-pCMV containing the SV40 origin of replication, a dhfr gene and the CMV immediate early promoter. The resulting plasmid was designated pSJ60.

The NcoI-HindIII fragment representing the humanized V_L was joined to a HindIII-NotI fragment representing a human c-Kappa CDNA in pS18. The humanized 1308F-Kappa gene on a SalI-NotI fragment was then combined with a PvuI-NotI fragment from pSJ37 carrying a poly A addition site and a PvuI-SalI fragment from pSV2-dhfr-pCMV, containing the SV40 origin of replication, a dhfr gene and the CMV immediate early promoter. The resulting plasmid was designated pSJ61.

Finally pSJ60 and pSJ61 were combined into a single plasmid containing both the light and heavy chains and expression signals. This was accomplished by isolating a PvuI-Bam HI fragment from pSJ61 carrying the light chain with a Pvu I - Bgl II fragment from pSJ60 carrying the heavy chain to generate pSJ66. (See Figure 5).

Example 4

Transfection of Cos1 cells with PSJ60 and PSJ61

Transfections were carried out according to the method of McCutchan and Pagano (J. Nat. Can. Inst. 41: 351-356, 1968) with the following modifications. COS 1 cells (ATCC

CRL1650) were maintained in a humidified 5% CO₂ incubator in 75 cm² tissue culture flasks in Dulbecco's Modified Eagle Medium (DMEM, GIBCO #320-1965) supplemented with 10% Fetal Bovine Serum (FBS, GIBCO #200-6140) and 2mM L-glutamine (BRL #320-5030) and passed at a split ratio of 1:20 when the cells had reached confluence. 48 hours prior to transfection, 5 100mm tissue culture dishes were seeded with 1.5×10^6 cells per dish in 12ml DMEM, 10% FBS, 2mM L-glutamine, 1% penicillin-streptomycin (P-S, GIBCO #600-5070). The day of the transfection, 120 ug each of the plasmids pSJ60 and pSJ61 were combined, ethanol precipitated, and aseptically resuspended in 2.5ml Tris-Buffered-Saline. The resuspended DNA was added dropwise, with mixing, to 10ml of DMEM containing 1 mg/ml DEAE-dextran (Pharmacia #17-0350-01) and 250 uM chloroquine (Sigma #C6628). The medium was removed from the COS1 cells in the 100 mm dishes and the cells were washed once with Dulbecco's phosphate buffered saline (D-PBS, GIBCO #310-4190), and 2.5ml DMEM supplemented with 10% NuSerum (Collaborative Research #55000) were added to each plate. 2.5ml of the DNA/DEAE-dextran/chloroquine mix were added dropwise to each plate, the plates swirled to mix the DNA, and were returned to the incubator. After 4 hours in the incubator, the supernatant was aspirated from the cells and the cells were washed once with 5ml D-PBS. The cells were shocked for 3 minutes by the addition of 5ml of 10% dimethylsulfoxide (DMSO) in D-PBS at room temperature. The DMSO was aspirated from the cells and the cells were washed with 5ml D-PBS. 14ml of DMEM/10% FBS/2mM L-glutamine/1%P-S were added to each plate and the plates were returned to the incubator.

Three days post-transfection the medium was removed from the plates, pooled, and stored at -20°C. The cells

were harvested, pooled, and seeded into 4 150cm² tissue culture flasks two with 40ml DMEM/10% NuSerum and two with 40ml DMEM/10% FBS/2mM L-glutamine. The medium was collected and the cells refed at 7, 10, and 14 days. In this way a total of 125ug of humanized 1308F antibody was accumulated in 310ml of medium supplemented with FBS and 85ug in 240ml of medium supplemented with NuSerum.

Example 5

Transfections of COS 1 cells with pSJ66

48 hours prior to transfection, 5 100mm tissue culture dishes were seeded with 1.5×10^6 cells per dish in 12ml DMEM, 10% FBS, 2mM L-glutamine, 1% penicillin-streptomycin (P-S, GIBCO #600-5070). The day of the transfection, 125ug of the plasmid pSJ66 were ethanol precipitated and aseptically resuspended in 1.0 ml Tris-Buffered-Saline. The resuspended DNA was added dropwise, with mixing, to 4.0ml of DMEM containing 1mg/ml DEAE-dextran (Pharmacia #17-0350-01) and 250uM chloroquine (Sigma #C6628). The medium was removed from the COS1 cells in the 100mm dishes and the cells were washed once with Dulbecco's phosphate buffered saline (D-PBS, GIBCO #310-4190), and 2.5ml DMEM supplemented with 10% NuSerum (Collaborative Research #55000) were added to each plate. 2.5ml of the DNA/DEAE-dextran/chloroquine mix were added dropwise to each plate, the plates swirled to mix the DNA, and were returned to the incubator. After 4 hours in the incubator, the supernatant was aspirated from the cells and the cells were washed once with 5ml D-PBS. The cells were shocked for 3 minutes by the addition of 5ml of 10% dimethylsulfoxide (DMSO) in D-PBS at room temperature. The DMSO was aspirated from the cells and the cells were washed with 5ml D-PBS. 14ml of DMEM/10% FBS/2mM

L-glutamine/1%P-S were added to each plate and the plates were returned to the incubator.

Three days post-transfection the medium was removed from the plates, pooled, and stored at -20°C. The cells were harvested, pooled, and seeded into 4 150cm² tissue culture flasks two with 40 ml DMEM10% NuSerum and two with 40 ml DMEM10% FBS/2mM L-glutamine. The medium was collected and the cells refed at 7, 10, and 14 days. In this way a total of 190ug of humanized 1308F antibody was accumulated in 310ml of medium supplemented with FBS and 120ug in 240ml of medium supplemented with NuSerum.

The concentration of humanized 1308F antibody secreted from the Cos1 cells into the medium was determined using a capture ELISA. Goat anti-human IgG Fc coated onto 96 well plates was used to capture the humanized antibody. Peroxidase conjugated goat anti-human whole IgG developed with a chromogenic substrate was then used to detect the bound antibody. A purified human IgG1/Kappa preparation was used to calibrate the assay.

Example 6

Neutralization of RSV with humanized 1308F

METHODS:

RSV was neutralized with either humanized 1308F from Cos cell supernatant or purified 1308F murine monoclonal antibody. This was done by incubating 50 plaque-forming units of RSV with serial 2-fold dilutions of antibody for 1.0 hour at 37°C. Confluent monolayers of Hep2 cells in 24 well panels were infected with 100µl of antibody treated virus, untreated control virus, and mock infected controls. Incubated for 1.5 hours at 37°C, humidified, and 5% CO₂ and overlaid with 1.5mL EMEM, 1% FBS, and 1% methyl cellulose. Cells were fixed and stained with glutaldehyde and crystal

violet on day 4. Plaques were counted in triplicate wells and plotted as percent neutralization. The results shown in Figure 6 indicate that both the purified murine 1308F monoclonal and the humanized 1308F monoclonal antibody at 5 to 10 ng per well yield similar 50% reductions in RSV plaques.

References:

1. Hall, C.B., Doiuglas, R.G., Geiman, J.M. et al., N.Engl.J.Med. 293:1343, 1975.
2. Hall, C.B., McBride, J.T., Walsh, E.E. et al., N.Engl.J.Med. 308:1443, 1983.
3. Hall, C.B., McBride, J.T., Gala, C.L. et al., JAMA 254:3047, 1985.
4. Wald, E.R., et al., J.Pediat. 112:154, 1988.
5. Kapikian, A.Z., Mithcell, R.H., Chanock, R.M. et al., Am.J.Epidemiol. 89:405, 1969.
6. Prince, G.A., Hemming, V.G., Horswood, R.L. et al., Virus Res. 3:193, 1985.
7. Hemming, V.G., Prince, G.A., Horswood, R.L. et al., J.Infect.Dis. 152:1083, 1985.
8. Wright, P.F., Belshe, R.B., et al., Infect.Immun. 37:397, 1982.
9. Conrad, D.A., Christenson, J.C., et al., Peditr.Infect.Dis.J. 6:152, 1987.
10. LoBuglio, A.F., Wheeler, R.L., Trang, J. et al., Proc.Natl.Acad. Sci. 86:4220, 1989.
11. Steplewski, Z., Sun, L.K., Shearman, C.W. et al., Proc.Natl.Acad. Sci. 85:4852, 1988.
12. Boulianne, G.L., Hozumi, N., Shulman, M.J. Nature. 312:643, 1984.
13. Sun, L.K., Curtis, P., Rakowicz-Szulczynska, E. et al., Proc.Natl.Acad. Sci. 84:214, 1987.
14. Liu, A.Y., Mack, P.W., Champion, C.I., Robinson, R.R., Gene 54:33, 1987.
15. Morrison, S.L., Johnson, M.J., Hersenber, L.A., Oi, V.T. Proc.Natl.Acad. Sci. 81:6851, 1984.
16. Morrison, S.L. Science 229:1202, 1985.
17. Sahagan, B.G., Dorai, H., Saltzgaber-Muller, J. et al., J.Immunol. 137:1066, 1986.

18. Taked, S., Naito, T., Hama, K., Noma, T., Honjo, T., Nature 314:452, 1985.
19. Carson, D.A., Freimark, B.D., Adv. Immunol. 38:275, 1986.
20. Beeler, J.A., et al., J.Virol. 63:2941-2950, 1989.
21. Coelingh, et al., Virology, 143:569-582, 1985.

WHAT IS CLAIMED IS:

1. A human-murine chimeric antibody, comprising:
a human antibody containing at least one CDR from each of the variable heavy and variable light chains of a murine monoclonal antibody against RSV.
2. An antibody as in Claim 1, wherein said murine monoclonal antibody is a neutralizing antibody against RSV.
3. An antibody as in Claim 1, wherein said murine monoclonal antibody is an antibody against RSV F protein.
4. An antibody as in Claim 3, wherein said murine monoclonal antibody is a neutralizing antibody against RSV F protein.
5. An antibody as in Claim 3, wherein:
said CDR comprises three complementarity determining regions from each of said variable heavy and variable light chains.
6. An antibody of Claim 5 wherein said murine antibody against RSV F protein is specific for antigenic site A of said protein.
7. A human antibody of Claim 5 wherein said murine antibody against RSV F protein is specific for antigenic site C of said protein.
8. A human antibody of Claim 7 wherein said murine antibody is MAb 1308F.
9. A human antibody as in Claim 8, wherein:
said three complementarity determining regions from said variable heavy chain of MAb 1308F comprise amino acid sequence Nos. 31 to 35, 47 to 60 and 99 to 106 and said three complementarity determining regions from said variable light chain of MAb 1308F comprise amino acid sequence Nos. 24 to 34, 50 to 56 and 89 to 97.

10. A process for preventing or treating a respiratory syncytial virus infection in an animal comprising:

administering to said animal an effective amount of a human antibody which contains at least one CDR from each variable heavy chain and variable light chain, of at least one murine monoclonal antibody against respiratory syncytial virus F protein.

11. The process of Claim 10 wherein:

said CDR's have three complementarity determining regions from each of said variable heavy and variable light chains.

12. A composition for preventing or treating respiratory syncytial virus infection in an animal comprising:

(a) an effective amount of a human antibody which contains at least one CDR from each variable heavy and variable light chains of at least one murine monoclonal antibody against respiratory syncytial virus F protein, and

(b) an acceptable pharmaceutical carrier.

13. A process for preventing or treating a respiratory syncytial virus infection in an animal comprising:

administering to said animal an effective amount of a plurality of human antibodies which contain at least one CDR from each variable heavy and variable light chain of at least one murine monoclonal antibody against RSV F protein.

FIG. 1A

DESIGN OF CDR-GRAFTED ANTI-RSV F PROTEIN V_H

Gln Val Gln Leu Val⁵ Gln Ser Gly Ala¹⁰ Glu Val Lys
 Gln Val Gln Leu Val Gln Ser Gly Ala Glu Val Lys
 * * * *
 Glu Val Gln Leu Gln Gln Ser Gly Ala Glu Leu Val

 Ser Cys Lys Ala²⁵ Ser Gly Tyr Thr Phe Asn³⁰ Ser Tyr
 * * * *
 Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys Asp Tyr
 Ser Cys Lys Ala Ser Gly Phe Asn Ile Lys Asp Pyr

 Pro Gly Gln Gly⁴⁵ Leu Glu Trp Met Gly⁵⁰ Ile Ile Asn
 * * * *
 Pro Gly Gln Gly Leu Glu Trp Ile Gly Trp Ile Asp
 * * * * CDR
 Pro Glu Gln Gly Leu Glu Trp Ile Gly Trp Ile Asp

 Ala Gln Lys Phe Gln Gly⁶⁵ Arg Val Thr Met⁷⁰ Thr Arg
 * * * *
 Asp Pro Lys Phe Gln Gly Arg Val Thr Met Thr Arg
 * * * *
Asp Pro Lys Phe Gln Gly Lys Ala Ser Ile Thr Ser

 Met Glu Leu Ser⁸⁵ Ser Leu Arg Ser Glu⁹⁰ Asp Thr Ala
 Met Glu Leu Ser Ser Leu Arg Ser Glu Asp Thr Ala
 * * * *
 Leu Gln Leu Ser Ser Leu Thr Ser Glu Asp Thr Ala

MATCH WITH FIG. 1B

- - - - -¹⁰⁵ - - - - -¹¹⁰ - - -
Thr Ser Ser Phe Asp Phe Trp Gly Gln Gly Thr Thr
 CDR3
 Thr Ser Ser Phe Trp Gly Gln Gly Thr Thr Leu Thr
 / J>>

SUBSTITUTE SHEET

FIG. 1B

Lys Pro Gly¹⁵ Ala Ser Val Lys Val²⁰ Human HV3 VH

L s Pro Gly Ala Ser Val Lys Val "CDR Grafted"
* * *

Arg Pro Gly Ala Leu Val Lys Leu Murine 1308F
VH

Tyr Met³⁵ His Trp Val Arg Gln Ala⁴⁰
* *

Tyr Ile Tyr Trp Val Arg Gln Ala
CDR 1 * *

Tyr Ile Tyr Trp Val Lys Gln Arg

Pro Ser⁵⁵ Gly Gly Ser Thr Ser Tyr⁶⁰
* * *

Pro Glu Asn Gly Asn Thr Val Phe
2

Pro Glu Asn Gly Asn Thr Val Phe

Asp Thr Ser⁷⁵ Thr Ser Thr Val Tyr⁸⁰

Asp Thr Ser Thr Ser Thr Val Tyr
* *

Asp Thr Ser Ser Asn Thr Ala Tyr

Val Tyr⁹⁵ Tyr Cys Ala¹⁰⁰

Val Tyr Tyr Cys Ala Tyr Tyr Gly

Val Tyr Tyr Cys Ala Tyr Tyr Gly
<<v / D

- - - - -
115

Leu Thr Val Ser Ser

Val Ser Ser

MATCH WITH FIG. 1A

DESIGN OF CDR-GRAFTED ANTI-RSV F PROTEIN V_L

Asp	Ile	Gln	Met	5	Thr	Gln	Ser	Pro	Ser	10	Thr	Leu	Ser
Asp	Ile	Gln	Met		Thr	Gln	Ser	Pro	Ser		Thr	Leu	Ser
		*									*	*	*
Asp	Ile	Lys	Met		Thr	Gln	Ser	Pro	Ser		Ser	Met	Tyr
Ile	Thr	Cys	Arg	25	Ala	Ser	Gln	Ser	Ile	30	Ser	Ser	Trp
			*					*			*	*	*
Ile	Thr	Cys	<u>Lys</u>		<u>Ala</u>	Ser	Gln	Asp	Ile		Asn	Arg	Tyr
										CDR 1			
Ile	Thr	Cys	Lys		Ala	Ser	Gln	Asp	Ile		Asn	Arg	Tyr
Gly	Lys	Ala	Pro	45	Lys	Leu	Leu	Ile	Tyr	50	Asp	Ala	Ser
											*		*
Gly	Lys	Ala	Pro		Lys	Leu	Leu	Ile	Tyr		<u>Arg</u>	<u>Ala</u>	<u>Asn</u>
		*				*			*				
Gly	Lys	Ser	Pro		Lys	Thr	Leu	Ile	His		Arg	Ala	Asn
Arg	Phe	Ser	Gly	65	Ser	Gly	Ser	Gly	Thr	70	Glu	Phe	Thr
Arg	Phe	Ser	Gly		Ser	Gly	Ser	Gly	Thr		Glu	Phe	Thr
									*		*	*	*
Arg	Phe	Ser	Gly		Ser	Gly	Ser	Gly	Gln		Glu	Tyr	Ser
Asp	Asp	Phe	Ala	85	Thr	Tyr	Tyr	Cys	Gln	90	Gln	Tyr	Asn
									*		*	*	*
Asp	Asp	Phe	Ala		Thr	Tyr	Tyr	Cys	<u>Leu</u>		<u>Gln</u>	<u>Phe</u>	<u>His</u>
*	*	*	*		*								
Glu	Asp	Met	Gly		Ile	Tyr	Tyr	Cys	Leu		Gln	Phe	His

2B
FIG.
MATCH

- - - - - 105 - - -
Gly Thr Lys Leu Glu Ile Lys

Gly Thr Lys Leu Glu Ile Lys

3 / 10

SUBSTITUTE SHEET

FIG. 2A

FIG. 2B

15 20
 Ala Ser Val Gly Asp Arg Val Thr - Human K102
 VL
 Ala Ser Val Gly Asp Arg Val Thr - "CDR Grafted"
 * * * VL
 Val Ser Leu Gly Glu Arg Val Thr - Murine 1308F
 VL
 35 40
 Leu Ala Trp Tyr Gln Gln Lys Pro
 *
Leu Asn Trp Tyr Gln Gln Lys Pro
 *
 MATCH WITH FIG. 2A Leu Asn Trp Phe Gln Gln Lys Pro
 55 60
 Ser Leu Glu Ser Gly Val Pro Ser
 * * *
Arg Leu Val Asp Gly Val Pro Ser
 CDR 2
 Arg Leu Val Asp Gly Val Pro Ser
 75 80
 Leu Thr Ile Ser Ser Leu Gln Pro
 Leu Thr Ile Ser Ser Leu Gln Pro
 *
 Leu Thr Ile Ser Ser Leu Glu Phe
 95 100
 Ser Tyr Ser - - -
 * * *
Glu Phe Pro Tyr Thr Phe Gly Gly
 CDR 3
 Glu Phe Pro Tyr Thr Phe Gly Gly
 <<v / J>>

Oligos used to make Hu1308 V_H

```
5' gcgaattccatggactggacctggagggctc  
    MetAspTrpThrPrpArgValPheCysLeuLeuAlaValAlaProGlyAlaHisSerGln  
5' ccATGGACTGGACCTGGAGGGTCTTCTGCTTGCTGGCTGTAGCACCCAGGTGCCCACTCCCAG  
1-----+-----+-----+-----+-----+-----+-----+-----+  
3' TACCTGACCTGGACCTCCCGAAGACGAACGACCACATCGTGTGCCACGGGTGAGGGTC
```

ValGlnLeuValGlnSerGlyAlaGluValLysLysProGlyAlaSerValLysValSer
GTGCAGCTGGTGCAGCTCTGGAGCTGAGGTGAAGAGCCTGGAGCCTCAGTGAAGGTTTCC

5 / 1 0

CysLysAlaSerGlyPheAsnIleLysAspTyrTyrIleTyrTrpValArgGlnAlaPro
TGCAAGGCATCTGGATTCAACATTAAAGCACTACTACATTACTGGTGGACAGGCTCCT
121
ACGTTCCGTAGACCTAAGTTGTAATTCCTGATGATGTAATAATGACCCACGCTGTCCGAGGA

181 GlyGlnGlyLeuGluTrpMetGlyTrpIleAspProGluAsnGlyAsnThrValPheAsp
GGACAAGGCTCGAGTGGATGGTTGGATTGACCCCTGAGAAATGGTAATACTGTGTTGAC
CCTGTTCCCGAGCTCACCTACCCAAACCTAACTGGGACTCTTACCATTATGACACAAACTG

MATCH WITH FIG. 3B

MATCH WITH FIG. 3A

ProLysPheGlnGlyArgValThrMetThrArgAspThrSerThrSerThrValTyMet
 CCGAAGTTCACGAGAGTCCACCATGACGAGGACACGTCACGACAGCATCTACATG
 241-----+-----+-----+-----+-----+-----+-----+
 GGCTTCAAGGTCCCGTCTCAGTGGTACTGGTCCCTGTGCAGGTGCTCGTGTTCAGATGTAC

GluLeuSerSerLeuArgSerGluAspThrAlaValTyThrCysAlaTyThrGlyThr
 GAGCTGAGCAGCCTGAGATCTGAGGACACGCGGTGTTACTGTGCGTACTACGGTACA
 301-----+-----+-----+-----+-----+-----+-----+
 CTCGACTCGTCCGACTCTAGACTCCTGTGCCGGCACATAATGACACGCATGATGCCATGT

SerSerPheAspPheTrpGlyGlnGlyThrThrLeuThrValSerSer
 AGCTCCTTTGACTTCTGGGGCCAAAGGCACCACTCTCACAGTGAGCTCA
 361-----+-----+-----+-----+-----+-----+-----+
 TCGAGGAAACTGAAGACCCCGGTTCCGGTGGTGAGAGTGTCACTCGAGTattcctagg 5'
 3' ggtgagagtgtcactcgagtattcctagggc

FIG. 3B

Oligos used to make Hu 1308 V_H

FIG. 4A

Oligos used to make Hu 1308 VL

cgcggtccatggacatgaggggtcccc

MetAspMetArgValProAlaGlnLeuLeuGlyLeuLeuLeuTrpLeuProGlyAla
 CCATGGACATGAGGGTCCCGCTCAGCTCCTGGGCTCCTGCTGCTGCTGCCAGGTGCC
 1 -----+-----+-----+-----+-----+-----+-----+
 TACCTGTACTCCAGGGCGAGTCGAGGACCCCGAGGACGACGAGACCGAGGGTCCACGG

LysCysAspIleGlnMetThrGlnSerProSerThrLeuSerAlaSerValGlyAspArg
 AAATGTGATATCCAGATGACCCAGTCTCTCCACCCCTGTCTGCATCTGTAGGACACAGA
 61 -----+-----+-----+-----+-----+-----+-----+
 TTACACTATAGGTCTACTGGGTGAGAGGAGGTGGGACAGACGTAGACATCTCTGTCT

ValThrIleThrCysLysAlaSerGlnAspIleAsnArgTyrLeuAsnTrpTyrGlnGln
 GTCACCATCACTTGCAAGGCGAGTCAGGACATTAATAGGTATTTAAACTGGTACCAGCAG
 121 -----+-----+-----+-----+-----+-----+-----+
 CAGTGGTAGTGAACGTTCCGCTCAGTCCCTGTAATTATCCATAAATTGACCATGGTCGTC

LysProGlyLysAlaProLysLeuLeuIleTyrArgAlaAsnArgLeuValAspGlyVal
 AAACCCGGGAAGCCCTAAGCTCCTGATCTATCGTGCAACAGATTGGTAGATGGGGTC
 181 -----+-----+-----+-----+-----+-----+-----+
 TTTGGGCCCTTTCGGGGATTCCGAGGACTAGATAGCACGTTTGTCTAACCATCTACCCAG

MATCH WITH FIG. 4B

MATCH WITH FIG. 4A

ProSerArgPheSerGlySerGlySerGlyThrGluPheThrLeuThrIleSerSerLeu
 CCATCAAGGTTTCAGCGGCAGTGGATCTGGGACAGAAATTCACCTCTCACCATCAGCAGCCTG
 -----+-----+-----+-----+-----+-----+-----+
 GGTAGTTCCAAGTCGCCGTCACCTAGACCCCTGTCTTAAGTGAGAGTGGTAGTCGTCGGAC

241

GlnProAspPheAlaThrTyrTyrCysLeuGlnPheHisGluPheProTyrThrPhe
 CAGCCTGATGATTTTGCAACTTATTACTGCCCTACAGTTTCATGAGTTTCCGTACACGTTTC
 -----+-----+-----+-----+-----+-----+-----+
 GTCGGACTACTAAACGTTGAATAATGACGGATGTCAAAGTACTCAAAGGCATGTGCAAG
 -----+-----+-----+-----+-----+-----+-----+
 3' gtgcaag

301

GlyGlyGlyThrLysLeuGluIleLys
 GGAGGGGGGACCAAGCTTGAAATAAAA 3'
 -----+-----+-----+-----+-----+-----+
 CCTCCCCCCTGGTTCGAACTTTATTTT 5'
 cctccccctgggttcgaacc 5'

361

FIG. 4B

8 / 10

SUBSTITUTE SHEET

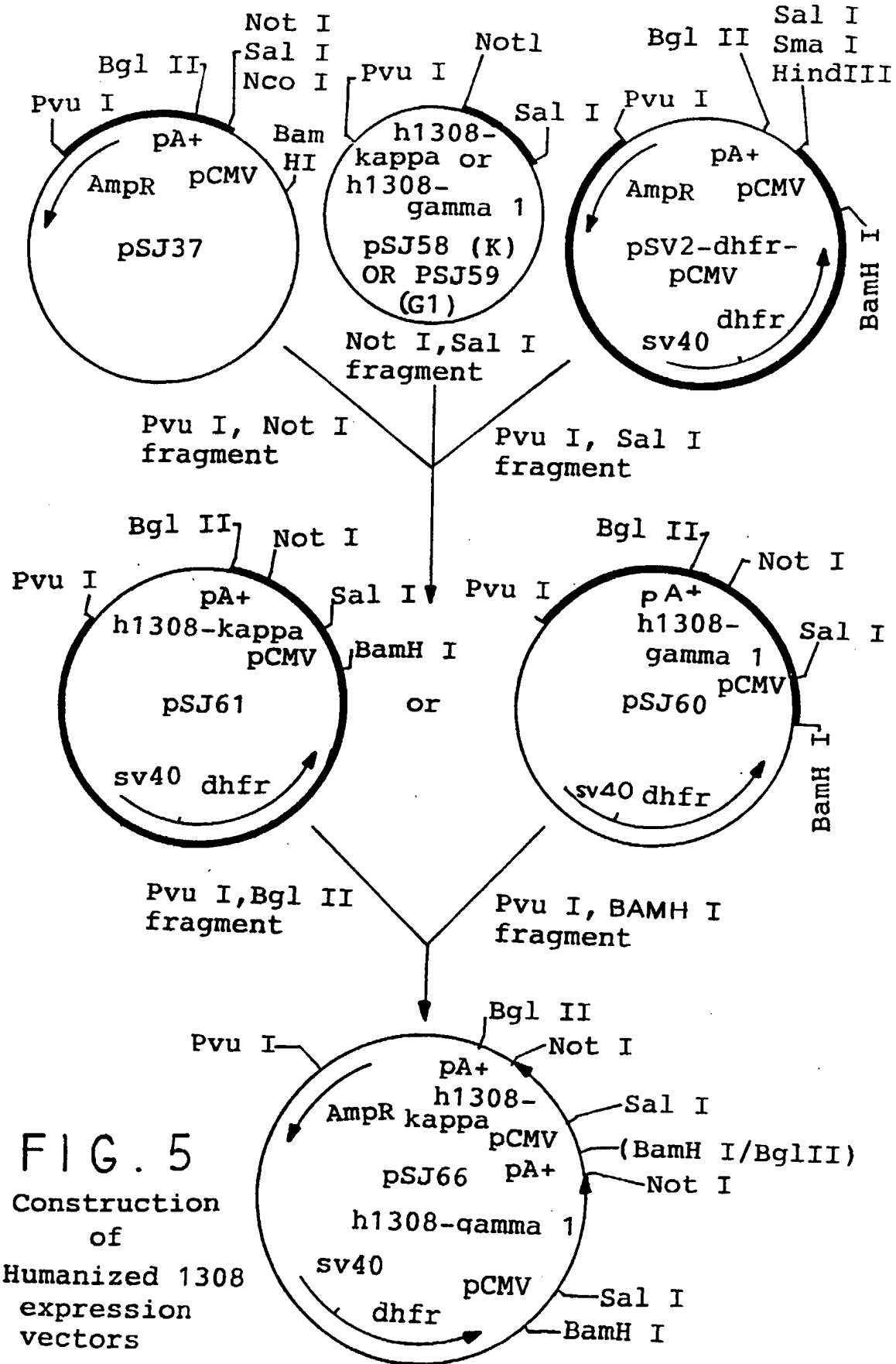
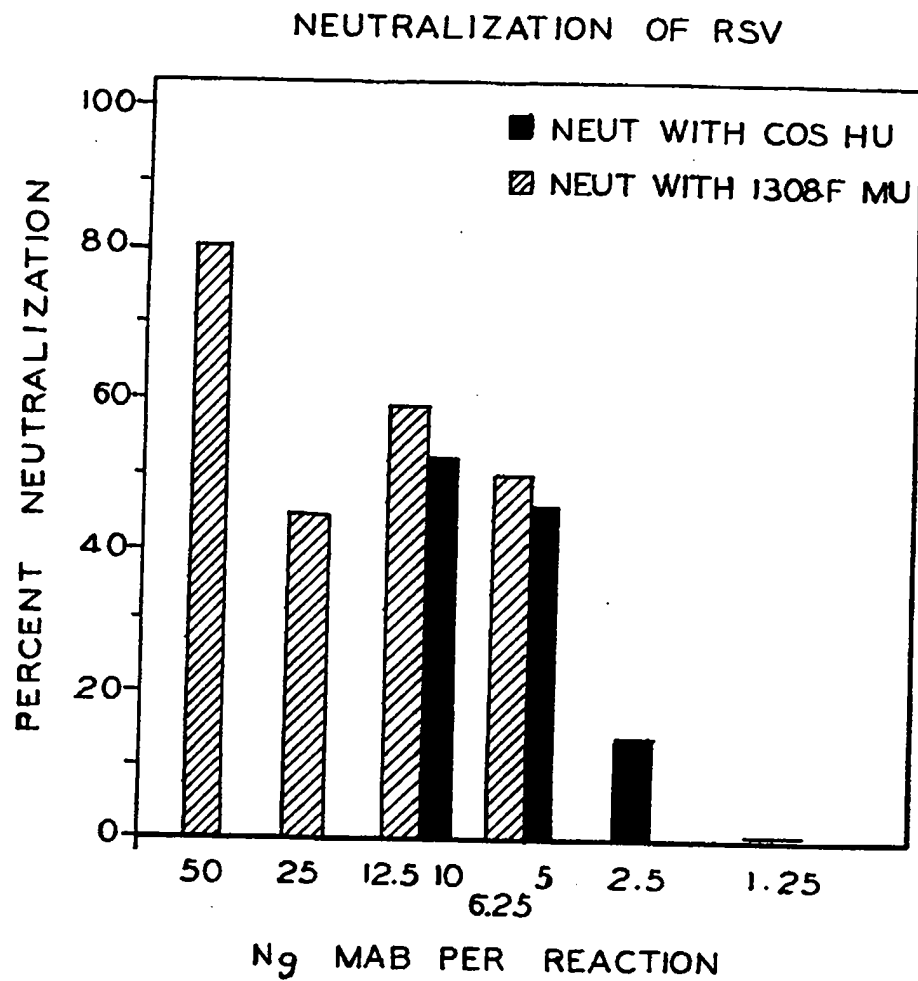


FIG. 5
Construction
of
Humanized 1308
expression
vectors

FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01168

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : C07K 15/28; C12N 5/20, 5/28; C12P 21/08; A61K 39/42, 39/395

US CL : Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 530/389.4, 388.15, 387.3; 435/240.27, 70.21; 424/85.8, 86; 935/95, 96, 99

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	Biotechnology, Volume 9, Number 3, issued March, 1991, P.R. Tempest et al., "Reshaping a human monoclonal antibody to inhibit human respiratory syncytial virus infection in vivo", pages 266 to 271, see entire document.	<u>1-5,12</u> 6-11,13
Y	Developmental and Biological Standarization, Volume 57, issued 1984, E.J. Stott et al., "The characterization and uses of monoclonal antibodies to respiratory syncytial virus", pages 237 to 244, see entire document.	1-13
Y	Nature, Volume 321, issued 29 May 1986, P.T. Jones et al., "Replacing the complementarity-determining regions in a human antibody with those from a mouse", pages 522 to 525, see entire document.	1-13

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:	
A document defining the general state of the art which is not considered to be part of particular relevance	*T* Inter document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
E earlier document published on or after the international filing date	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
U document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
O document referring to an oral disclosure, use, exhibition or other means	*A* document member of the same patent family
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

01 April 1993

Date of mailing of the international search report

14 APR 1993

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Facsimile No. NOT APPLICABLE

Authorized officer

JACQUELINE G. KRIKORIAN

Telephone No. (703) 308-0196

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01168

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

530/389.4, 388.15, 387.3; 435/240.27, 70.21; 424/85.8, 86; 935/95, 96, 99

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

CAS Online, Biosis, Medline, WPI, APS, Genbank

search terms: antibodies, RSV-F protein, respiratory syncytial virus, treatment, chimeric human-mouse antibodies, sequences disclosed